Ompompanoosuc River
Vermont

Union Village Dam Dam-Break Flood Analysis

February 1984

US Army Corps
of Engineers
New England Division

TC423
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1984 Basin, Vermont: dam-break flood
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Quality Section, Water Control
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control. 4. Connecticut River
watershed (Vt.)--Flood control.
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Connecticut River Basin, Vermont.

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UNION VILLAGE DAM
CONNECTICUT RIVER BASIN
VERMONT

DAM-BREAK FLOOD ANALYSIS
BY
HYDRAULICS AND WATER QUALITY SECTION
WATER CONTROL BRANCH
ENGINEERING DIVISION

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

FEBRUARY 1984

UNION VILLAGE DAM PROJECT
DAM-BREAK FLOOD ANALYSIS

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DAM-BREAK FLOOD ANALYSIS

1. INTRODUCTION AND PURPOSE

This report presents the findings of a dam-break flood analysis performed for the Union Village Dam, an existing Corps of Engineers flood control project, located on the Ompompanoosuc River at Union Village, Vermont. The dam is situated approximately 3.5 miles upstream from the Ompompanoosuc's confluence with the Connecticut River. Included in the report are:

Description of the pertinent features of the dam.

Procedure used for the analysis.

Assumed dam-break conditions and resulting effect on downstream flooded areas.

Effects of varying conditions (sensitivity tests) on the resulting downstream flood.

The only purpose of this study was to provide quantitative information for emergency planning use in accordance with Corps of Engineers Regulation (ER 1130-2-419), not for any possibility of a dam-break at Union Village Dam.

2. PROCEDURE

The Union Village Dam-Break Analysis utilized the "National Weather Service Dam-Break Flood Forecasting Computer Model," developed by D. L. Fread, Research Hydrologist, Office of Hydrology, National Weather Service, NOAA, Silver Spring, Maryland 20910. Input to the model consisted of: (a) storage characteristics of the reservoir, (b) selected geometry and duration of the breach development, and (c) hydraulic characteristics of the downstream river channel including tributary inflows, hydraulic roughness coefficients, and active and inactive flow regions. Based on input data, the model computes the dam-break outflow hydrograph and routes it downstream. Dynamic unsteady flow routing is performed by a "honing" iterative process governed by requirements of both the principle of conservation of the mass and the principle of the conservation of momentum. The analysis provides output on the attenuation of the flood hydrograph, resulting flood stages, and timing of the flood wave as it progresses downstream.

The approach used in this hypothetical dam-break analysis was to first apply the model using a selected set of conditions considered reasonably possible to exist in a failure situation. The flood wave resulting from this analysis is termed the Base Flood Condition. Because any one of the major variables used in the model (initial pool elevation, antecedent riverflow, time of breach development, etc.) could in fact have different values or occur in different combinations from those used in the Base Flood determination, sensitivity analyses were employed to determine the effects upon the flood wave resulting from changed values of these parameters.

3. DESCRIPTION OF STUDY AREA

a. General. The study area extends from the Union Village Dam, downstream along the Ompompanoosuc River to the Connecticut River, then downstream along the Connecticut to the Wilder Hydroelectric Project, then downstream to just beyond the confluence of the Ottauquechee River, a distance of approximately 19 river miles. Along the study reach, the drainage area increases from 126 square miles at Union Village Dam to 136 square miles at the mouth of the Ompompanoosuc River and then to 3,375 square miles at Wilder Dam. Major tributaries in the Ompompanoosuc River basin include the West Branch Ompompanoosuc River and Lake Fairlee Brook. The main purpose of Union Village Dam is to desynchronize floodflows on the Connecticut River and to provide flood protection for the community of Union Village just below the dam. Presently there is no recreation pool maintained at the project. A map of the Ompompanoosuc River basin is shown on plate 1 and a map showing the relationship of the Union Village project to the Connecticut River basin is provided on plate 2.

b. Union Village Dam. This dam, constructed in Union Village, Vermont by the Corps of Engineers as a single-purpose flood control project was placed in operation in October 1949. The project is 1 of 16 flood control reservoirs within the Connecticut River basin operated by the Corps. Union Village Dam is a rolled earth and rockfill embankment structure, with a length of 1,100 feet and a maximum height of 170 feet. Top width of the dam is 30 feet and the side slopes vary from 1V on 2.5H to 1V on 3H. A photo, general plan and cross section are shown on plates 3, 4 and 5. When filled to spillway crest elevation, the reservoir has a flood control capacity of 38,000 acre-feet, equivalent to 5.65 inches of runoff from the 126-square mile drainage area. The reservoir length formed by this 740-acre pool is 3.5 miles, and other pertinent data are listed in table 1.

c. Downstream Valley

(1) General. The river downstream from Union Village Dam

TABLE 1

UNION VILLAGE DAM PROJECT
PERTINENT DATA

Location:	Ompompanoosuc River, Union Village, Vermont	
Drainge Area:	126 Square Miles	
Reservoir:		
	Outlet Works Intake (Invert)	420 Feet NGVD
	Winter Pool	440 Feet NGVD
	Spillway Crest	564 Feet NGVD
Dam:		
	Type	Rolled Earth and Rock Embankment
	Length	1,100 Feet
	Top Width	30 Feet
	Top Elevation	584 Feet NGVD
	Maximum Height	170 Feet
Spillway:		
	Type	Uncontrolled, Ogee Weir, Chute Spillway
	Length	388 Feet
	Crest Elevation	564 Feet NGVD
	Surcharge	15 Feet
	Capacity	84,900 CFS
Outlet Works:		
	Type	Circular Conduit
	Length	1,167 Feet
	Gates	
	Number and Type:	2 Broome
	Size:	7'6" x 12'0"
	Normal Regulated Maximum Q	2,100 CFS
	Maximum Capacity at Spillway Crest	7,500 CFS

travels through the small community of Union Village prior to reaching the Connecticut River. Through this reach, the river normally ranges from 50 to 900 feet in width with a corresponding flood plain ranging from zero near the dam to as much as 1,400 feet in width near the confluence of the Connecticut. The river channel drops approximately 60 feet between Union Village Dam and the confluence with the Connecticut River, a distance of approximately 3.5 miles. The Connecticut River from the Ompompanoosuc to the confluence with the Ottauquechee is much flatter, with an average slope of about 3 feet/mile.

The Wilder Hydroelectric Project, located on the Connecticut River approximately 8 miles downstream from the confluence with the Ompompanoosuc River (11.2 miles downstream from Union Village Dam), creates a backwater effect during normal operation. The effect extends upstream into the Ompompanoosuc River controlling its stage during times of low flows.

The study reach is crossed by State Routes 10 and 132, US Routes 91, 4 and 89, two Boston & Maine railroad lines, and one local road. Nondamaging channel capacity below Union Village Dam as reported in the Corps Ompompanoosuc River Regulation Manual, is 2,100 cfs.

(2) Wilder Hydroelectric Project. This project is a run-of-river generating facility with limited storage, including a concrete gravity dam with two skimmer gates, six tainter gates and four stanchion bays. The nonoverflow section of the crest has an elevation of 393 NGVD. The reservoir has a volume of 34,600 acre-feet between elevation 385 (full reservoir - top of stanchion boards) and 355 (tainter gate crest). Normal operation ranges between 385 and 380 and the usable storage amounts to about 13,350 acre-feet. A 46-mile reservoir length is produced by a full pool.

4. ASSUMED DAM-BREAK CONDITIONS

a. General. The magnitude of a flood resulting from the hypothetical failure of Union Village Dam is a function of many different parameters including size of the dam and reservoir, size of the breach, initial pool level at both the breached dam and the downstream dam, rate of breach formation, channel and overbank roughness and antecedent flow conditions. Engineering assumptions of conditions which could reasonably be expected to exist prior to a failure of Union Village Dam and which were used in the base flood analysis are presented below.

b. Selected Base Flood. Parameters and their values used in the base flood profile analysis are presented in the following tabulation:

Antecedent Flow - Although the flow of 2-3 November 1927 was the flood of record in the Ompompanoosuc basin, it was not used for modelling purposes since sufficient data were not available. Instead, the routed flood data of the 9-22 March 1936 storm, as presented in the Corps Connecticut River Basin Comprehensive Plan, were used. This flood produced equivalent flood stages to those of the 1927 event. A constant flow rate of 7,500 cfs from Union Village Dam, equivalent to the maximum outlet works capacity of the pool at spillway crest, was selected for this study to provide computational stability in the numerical simulation technique. Actual releases equivalent to the nondamaging channel capacity of 2,100 cfs are normally made (this difference in flow would have little effect on dam failure flood wave elevations). At Wilder Dam, a constant flow rate of 11,200 cfs, equivalent to the maximum combined turbine and large skimmer gate capacities for the initial pool height, was chosen to approximate the actual operation which would occur at Wilder Dam during high flow conditions on the Connecticut River. It was also assumed that the Wilder tainter gates would be fully opened due to the high initial flow conditions and that the four stanchion bays were opened instantaneously at the start of the Union Village Dam failure.

Initial Pool Level - Union Village Dam: water surface at spillway crest elevation 564 NGVD. Wilder Hydroelectric Project: water surface at minimum normal operating pool level of 380.0 NGVD.

Breach Invert - Elevation 425 NGVD.

Breach Dimension - Width = 320 feet; side slopes - 2V on 1H

Time to Complete Formation of Break - 1 hour

Downstream Channel Roughness - Manning's "n" = 0.06 to 0.1 from Union Village Dam to a point one-half mile downstream; 0.09 to 0.12 from a point one-half mile downstream to the Connecticut River; 0.06 to 0.1 on the Connecticut River from the Ompompanoosuc River to the Wilder Hydroelectric Project; 0.04 to 0.08 from the Wilder Hydroelectric Project to the end of the study reach.

Downstream Dam Failure - Wilder Dam was assumed to remain intact.

5. RESULTS

The resulting peak stage flood profile and inundation areas for the base flood conditions are shown on plates 6 and 7. Timing of the peak and leading edge of the flood wave are also indicated on the plan and profile.

Development of the peak stage profile, and discharge and stage hydrographs for three stations downstream from Union Village Dam is shown on plate 8. The stations are located 0.33, 3.19, and 9.55 miles downstream from the dam.

The peak dam-break discharge from Union Village Dam would be 760,900 cfs, producing a 62-foot rise above the normal river level at a point 0.15 mile downstream from the dam. At a point 1.9 miles downstream from the dam, the peak flow would be reduced to 532,500 cfs with an attendant river rise of 62 feet above normal. At the confluence of the Ompompanoosuc River with the Connecticut River (3.5 miles from the dam) the peak flow would attenuate to 407,100 cfs with a resultant peak stage of 38 feet greater than normal stage.

As the floodflow passes into the Connecticut River, the peak discharge increases to 416,000 cfs as a result of the high antecedent flow entering from the upstream Connecticut River basin. From this point, the flow attenuates over the next 7.7 miles such that the peak flow at Wilder would be 167,300 cfs. The corresponding peak stage would reduce to only 6 feet above normal stage mainly due to the opening of the stanchion bays at the start of failure at Union Village Dam.

At a point 0.4 mile below Wilder Dam, the peak flow would be 166,200 cfs with an attendant peak stage of 34 feet over the normal flow stage. At the confluence of the Ottauquechee River, approximately 7 miles downstream from Wilder Dam, the dam-break analysis was terminated since the calculated water surface elevation at this point approximated the experienced November 1927 high watermark.

6. SENSITIVITY TESTS

In addition to analysis under the assumed base flood conditions, subsequent studies were made to determine the sensitivity of certain selected parameters on the resulting downstream flood, by applying the model to the same data set used for the base flood except that one parameter was varied in each simulation.

Following is a listing of variables used in the sensitivity testing and the results of each test.

a. Initial Pool Level. While a full reservoir condition (spillway crest elevation = 564 feet NGVD) was assumed for the base flood, a sensitivity test was made using one-half pool as the initial condition (elevation 532 NGVD). The analysis shows that the discharge would decrease by 42 percent immediately below the dam with an associated drop in stage of about 16 feet from the base flood condition. The stage difference decreased between 3 and 7 feet on the Connecticut River. Comparative water surface profiles are shown on plate 9.

b. Antecedent Flow Conditions. Base flood analysis assumed a high flow occurring in the river at the time of dam-break. This was considered appropriate since if a breach were to occur, it is quite conceivable that it would do so at a time of abnormally high flow conditions. Antecedent flow conditions were selected to equal the March 1936 floodflows as delineated in the Connecticut River Basin Comprehensive Plan and as modified by the existing system of Corps of Engineers flood control reservoirs, namely, the Union Village and North Hartland projects.

Specifically, model input data for inflow into Union Village was developed by routing the estimated recessional portion (initiating at the assumed peak rate of 12,300 cfs) of the March 1936 flood hydrograph through Union Village reservoir assuming the pool initially filled to spillway crest level. The hydrograph resulting from the flow over the spillway and assumed constant flow of 7,500 cfs from Union Village Dam's regulating gates was then routed downstream to the Connecticut and then to Wilder Dam.

Antecedent inflow from the Connecticut River basin above the Ompompanoosuc River was accounted for by using the coincident March 1936 hydrograph. At Wilder Dam, it was assumed that the water surface was initially at elevation 380 feet NGVD (normal minimum operating level) with the tainter gates wide open and a constant flow equal to 11,200 cfs, discharging from the turbines and the large skimmer gate. At the beginning of dam failure, it was assumed that the stanchion flashboards would be released and tainter gates opened.

Floodflows were routed downstream from Wilder Dam along the Connecticut River to a point 1 mile downstream from the confluence with the Ottauquechee. Inflows to the Connecticut River in this reach from the White, Mascoma and Ottauquechee Rivers, which enter 12, 14 and 18 miles, respectively, downstream from Union Village Dam were also accounted for in the dam-break hydrograph routing analysis. March 1936 hydrographs for each stream were initiated with their concurrent respective flow rates of 10,000, 6,700 and 930 cfs and continued through the remainder of the routing analysis.

The adopted antecedent flows at the start of failure and the comparative experienced 1927 and 1936 discharges are shown on table 2.

A sensitivity analysis was made assuming lower antecedent riverflows and the resulting comparative flood stages are shown on plate 9. Estimated average daily flows were used as the antecedent conditions. The tainter gates and the stanchion bays at Wilder Dam were again assumed to open instantaneously at the start of Union Village Dam failure. The dam-break profiles show close agreement generally along the Ompompanoosuc portion of the study area, but display larger variation in the Connecticut River reach. The larger variation is the result of the greater antecedent floodflow assumed to exist in the Connecticut River for the base flood analysis.

c. Operation of Wilder Dam. Selected operation of Wilder Dam included opening of all gates and removal of the stanchion flashboards with the initial pool level set at 380 NGVD (minimum normal operating level). As a result of the wide variation in possible operating conditions, a sensitivity test was completed assuming that the stanchion flashboards were not removed. The result of this comparison on flood profiles is shown on plate 10.

If the stanchion flashboards remain, floodflows would overtop the dam by about 6 feet. Under this condition, assuming the Wilder Dam remains intact, flood stages immediately below the dam would be 4 feet less than the base flood condition.

d. Channel Roughness. Sensitivity tests were made to determine the effect of Manning's "n" value on downstream flood attenuation, resulting stages and timing. Tests were made with Manning's "n" values 20 and 40 percent greater than that used in the base flood condition. A lower channel roughness (smaller "n" value) results in faster movement of the flood wave and less attenuation. Increasing the channel roughness (greater "n" value) results in the reverse occurring. However, as illustrated on plate 10, the resulting variations in the downstream profiles were negligible, amounting to a change of only a few feet from that of the base flood. The most significant effect of varying the channel roughness was the timing difference of the peak flood stage. At Wilder Dam, this varied from approximately 2.3 to 2.7 hours for the lowest to the highest "n" values, respectively.

TABLE 2

ANTECEDENT FLOODFLOW CONDITIONS

Location	Adopted Antecedent Flows (cfs)	Experienced Nov 1927 Flows (cfs)	Experienced March 1936 Flows (cfs)
Ompompanoosuc River			
0.4 mile upstream from Union Village Dam	12,300	12,000*	7,300*
Union Village (0.4 mile downstream from Union Village Dam)	7,500	12,000*	7,300*
Connecticut River			
White River Junction USGS gage (12 miles downstream from Union Village Dam)	75,400	136,000*	120,000* (109,000**)

* Estimated peak flow

** Estimate of experienced discharge on the Connecticut River at White River Junction occurring simultaneously with the peak flow rate into Union Village Reservoir

e. Breach Width. The breach width was set at 320 feet for the base flood analysis. For sensitivity testing, two additional cases were analyzed with breach widths of 160 and 450 feet. As shown by the comparative profiles on plate 11, the breach width variations resulted in less than 8 feet of change in stage from the base flood condition in the upper portion of the study reach but these differences diminished greatly in the downstream region.

f. Duration of Dam-Break. Selected duration of breach development for the base flood condition was 1 hour for sensitivity testing; analyses were also made for 3 and 5 hours. The longer breach development duration schemes of 3 and 5 hours resulted in stage decreases of 12 and 14 feet, respectively, immediately below the dam, and almost negligible differences along the main stem Connecticut River. These results are shown on plate 11.

7. DISCUSSION

The dam-break analysis for Union Village Dam was based on the engineering application of certain laws of physics, considering the hydrologic and hydrualic characteristics of the project and downstream channel, and conditions of failure. Due to the highly unpredictable nature of a dam-break and the ensuing sequence of events, results of this study should not be viewed as exact but only as an approximate quantification of the dam-break flood potential. For purposes of analysis, downstream conditions are assumed to remain constant and no allowance is made for possible enlargement or relocation of the river channel due to scour or the temporary damming effect of debris, all of which affect, to some extent, the resulting magnitude and timing of flooding downstream.

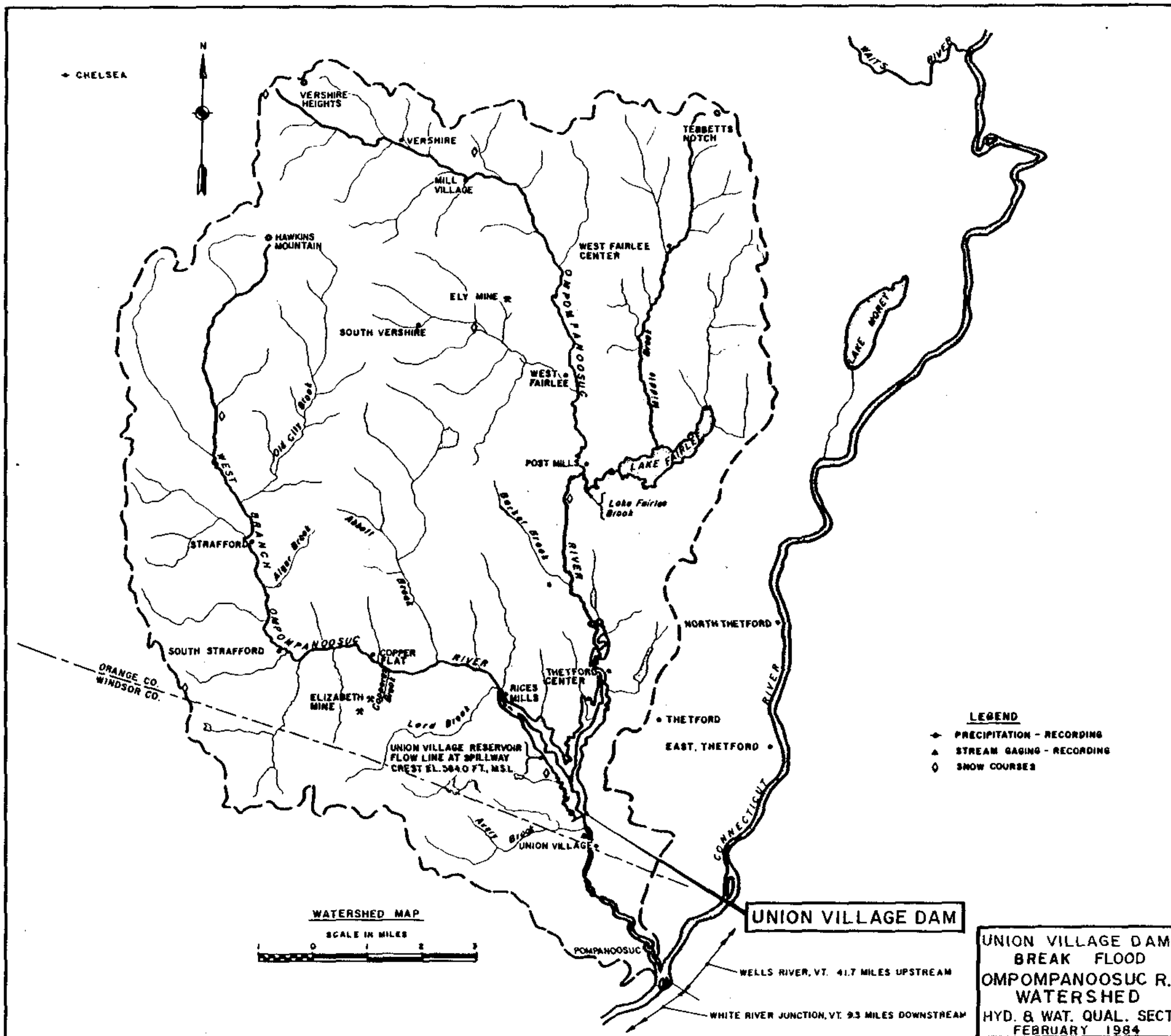
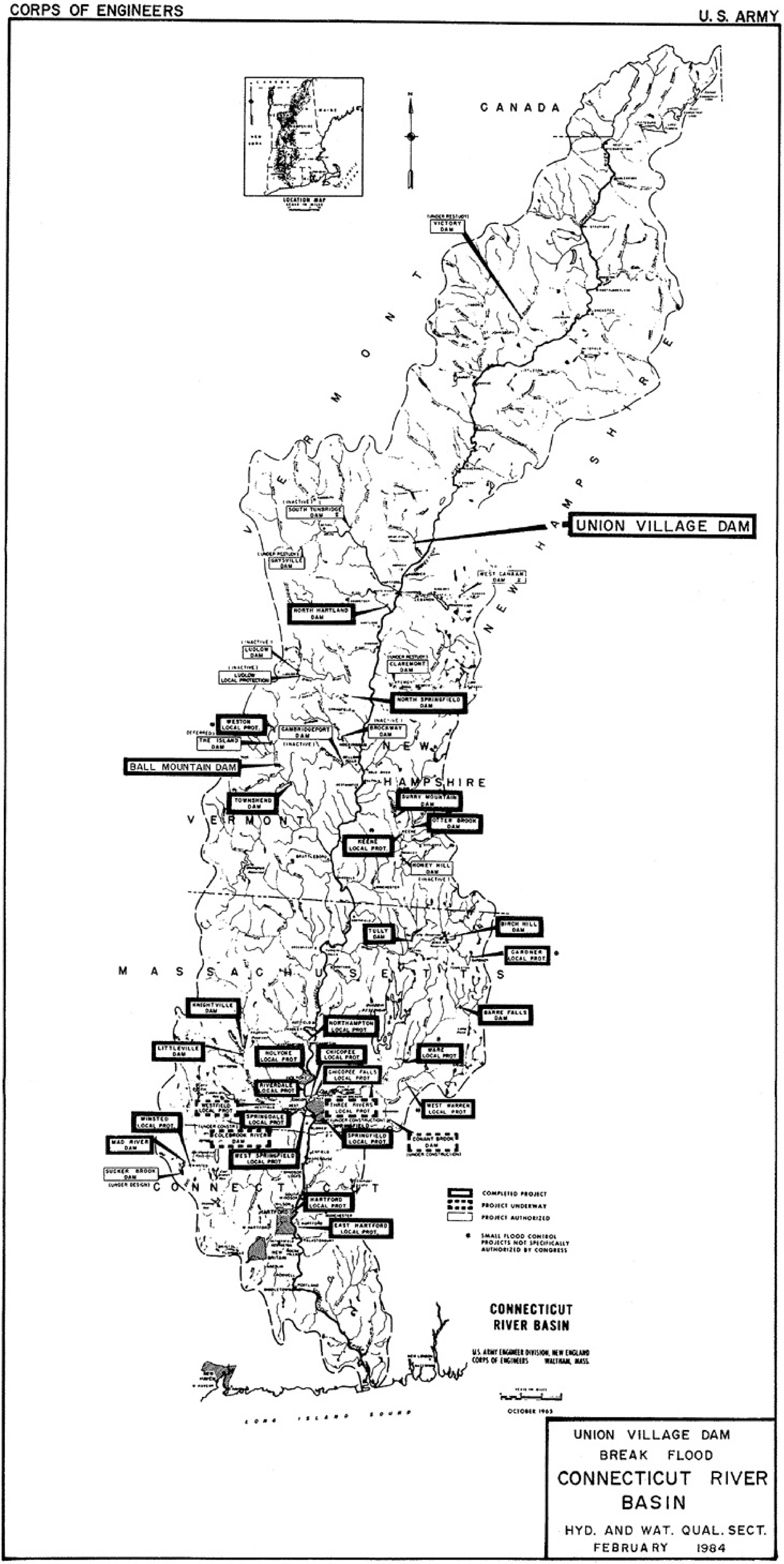

CHELSEA
N
VERSHIRE HEIGHTS
VERSHIRE
MILL VILLAGE
TEBBETTS NOTCH
WAITS RIVER
HAWKINS MOUNTAIN
WEST FAIRLEE CENTER
ELY MINE
SOUTH VERSHIRE
WEST FAIRLEE
LAKE MOREY
OMPOMPANOOSUC
Middle Brook
Old City Brook
WEST BRANCH
POST MILLS
LAKE FAIRLEE
Lake Fairlee Brook
Abbott Brook
Blaisdell Brook
STRAFFORD
Alger Brook
Brook
RIVER
NORTH THETFORD
SOUTH STRAFFORD
OMPOMPANOOSUC
COPPER FLAT
RIVER
THETFORD CENTER
ORANGE CO.
WINDSOR CO.
RICES MILLS
ELIZABETH MINE
Copperas Brook
Lord Brook
THETFORD
EAST THETFORD
CONNECTICUT RIVER
UNION VILLAGE RESERVOIR FLOW LINE AT SPILLWAY CREST EL. 584.0 FT. MSL.
Ardis Brook
UNION VILLAGE
LEGEND
PRECIPITATION - RECORDING
STREAM GAGING - RECORDING
SNOW COURSES
UNION VILLAGE DAM
WATERSHED MAP
SCALE IN MILES
1 0 1 2 3
POMPANOOSUC
WELLS RIVER, VT. 41.7 MILES UPSTREAM
WHITE RIVER JUNCTION, VT. 9.3 MILES DOWNSTREAM
UNION VILLAGE DAM
BREAK FLOOD
OMPOMPANOOSUC R.
WATERSHED
HYD. & WAT. QUAL. SECT.
FEBRUARY 1984

Plate 1



UNION VILLAGE DAM
BREAK FLOOD
CONNECTICUT RIVER BASIN
HYD. AND WAT. QUAL. SECT.
FEBRUARY 1984

PLATE 2

VIEW OF UNION VILLAGE DAM

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

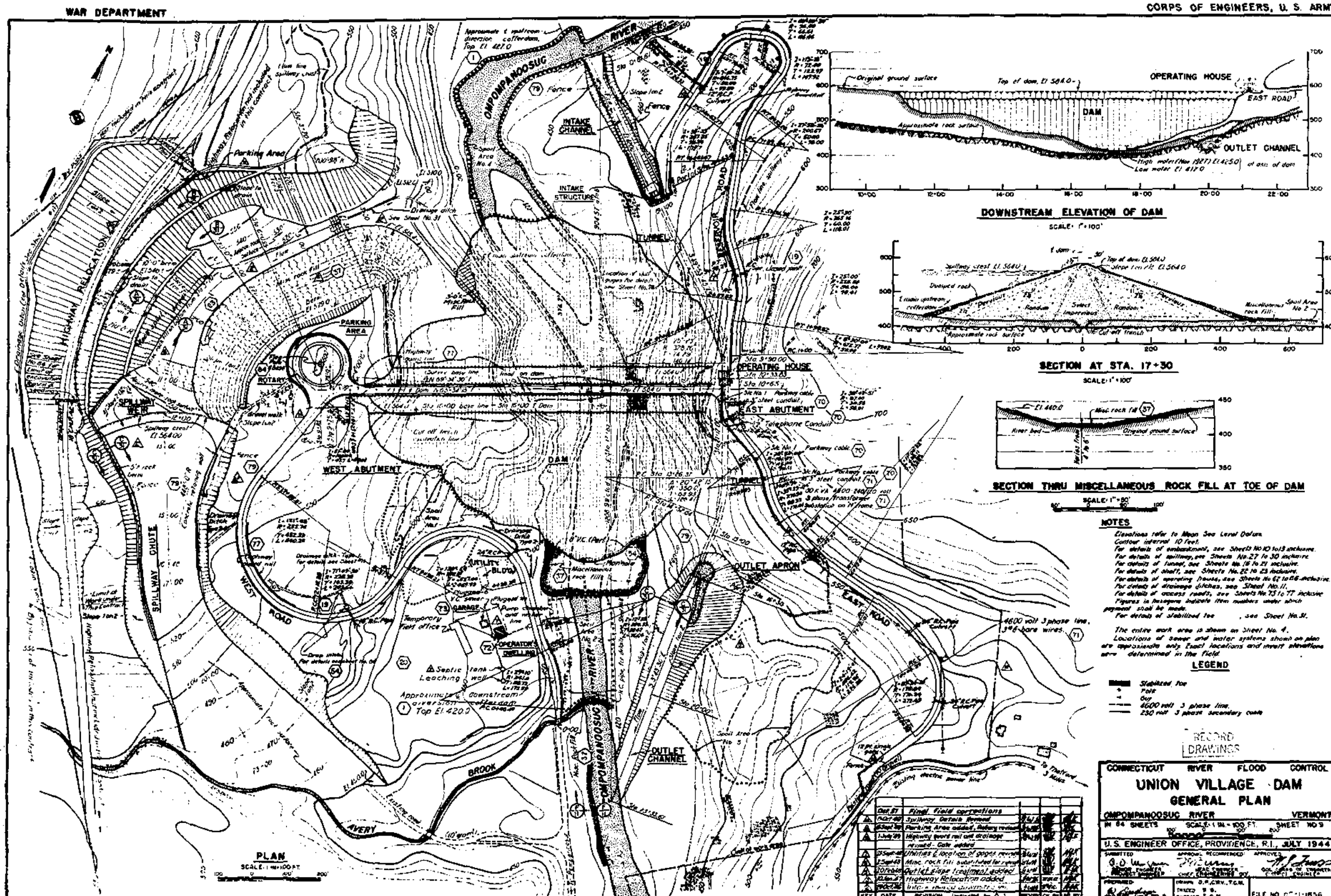
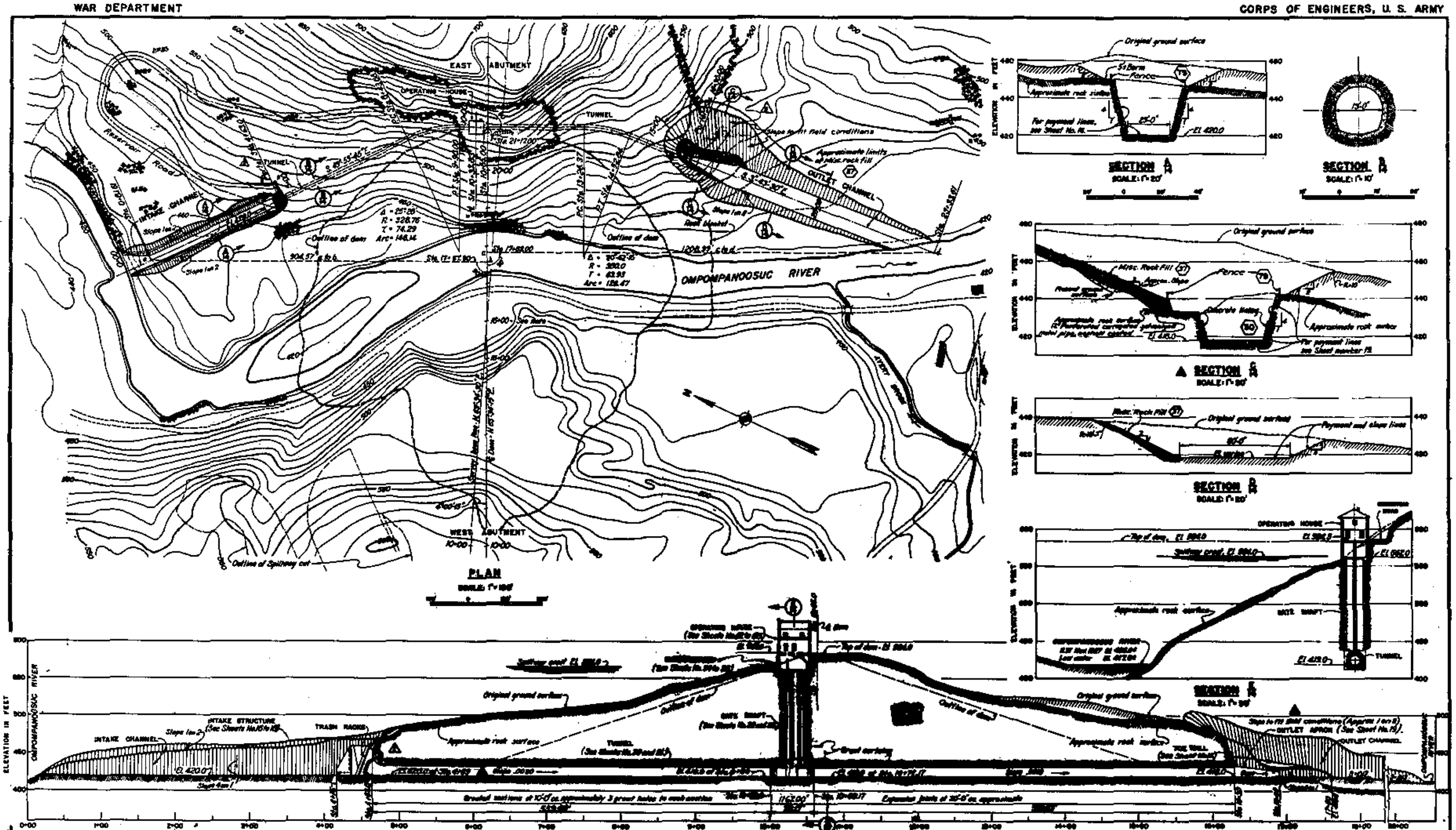


PLATE 4

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY



NOTES

Elevations refer to Mean Sea Level Datum.

The survey base line and the center line of dam intersect at Sta. 16+00 of both lines.

Contour interval 10 feet.

The locations of the upper and lower tunnel portals and the alignment of the intake and outlet channels were subject to change depending on conditions disclosed in the field.

All Const. joints in the tunnel between Sta. 4+63.00 and Sta. 16+30.00, were provided with copper water stops.

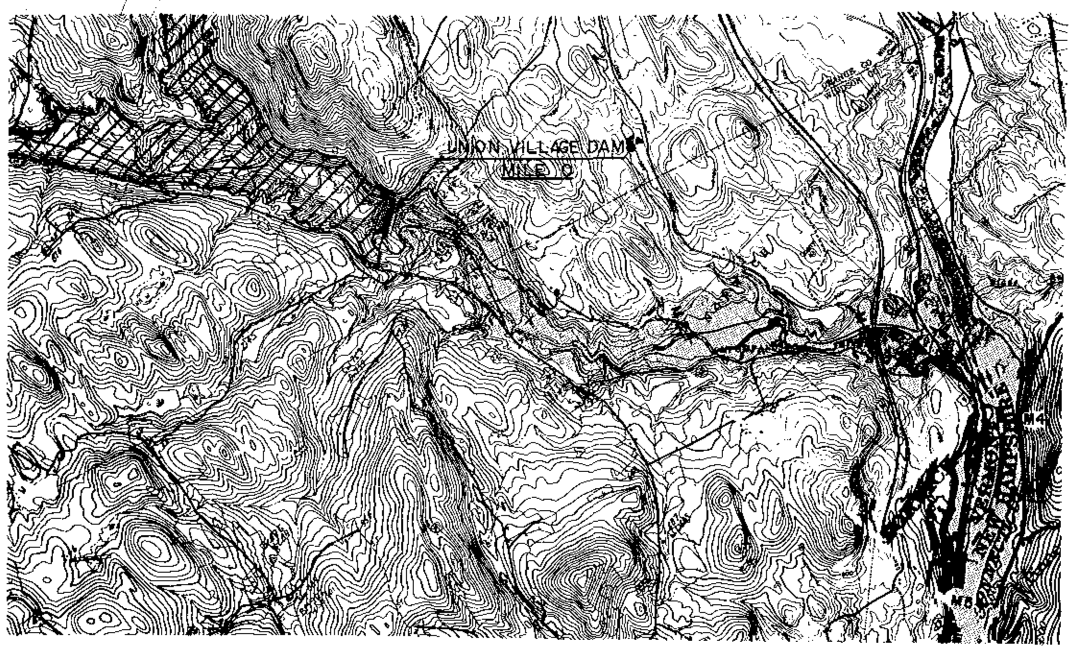
RECORD DRAWINGS

CONNECTICUT RIVER FLOOD CONTROL
UNION VILLAGE DAM
OUTLET WORKS
PLAN AND SECTIONS
OMPOMPANOOSUC RIVER — VERMONT
IN 64 SHEETS — SCALES AS SHOWN — SHEET NO. 14
U.S. ENGINEER OFFICE, PROVIDENCE, R.I., JULY 1944
FILE NO. OT-1-1661

PLATE 5

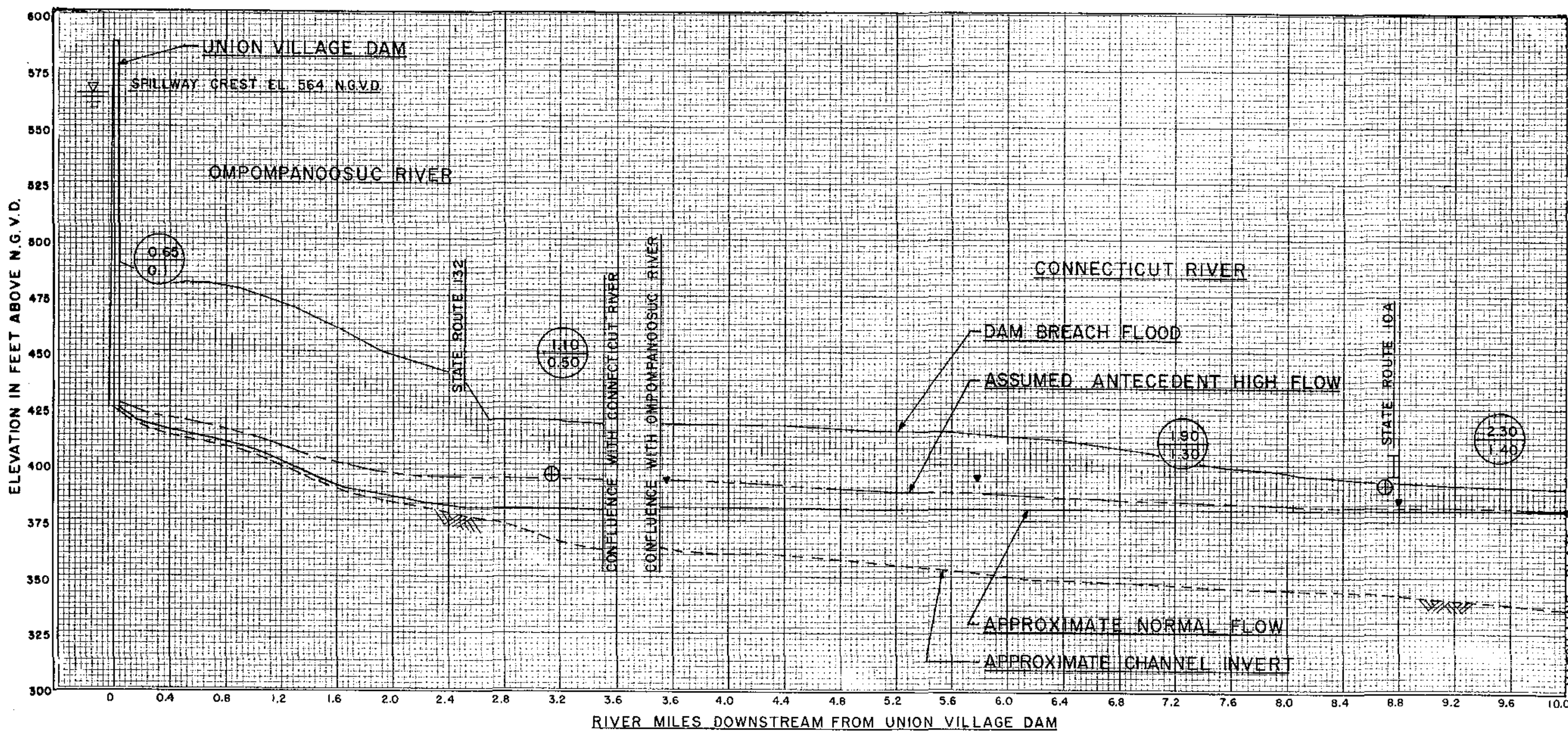
U.V. 14

CORPS OF ENGINEERS — U. S. ARMY



LEGEND

1.10 / 0.50	HOURS FROM START OF FAILURE TO PEAK STAGE / HOURS TO INITIAL RIVER RISE
+ MI	RIVER MILES DOWNSTREAM FROM DAM
	LIMITS OF BREACH FLOOD
⊕	EXPERIENCED MARCH 1936 FLOOD ELEVATIONS
▼	EXPERIENCED NOVEMBER 1927 FLOOD
I	BRIDGE



SCALE IN MILES

0 0.5 1.0

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

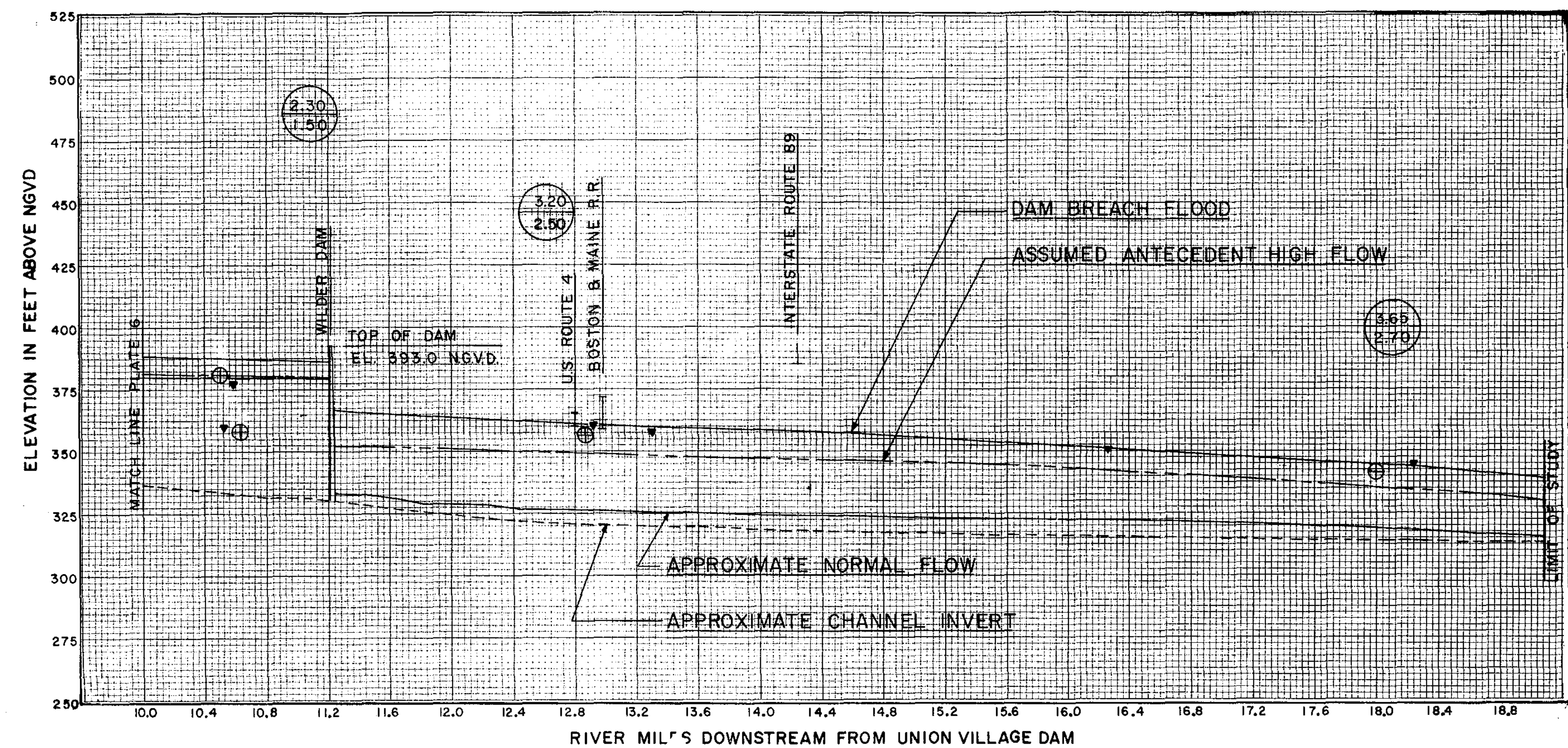
CONNECTICUT RIVER BASIN

UNION VILLAGE DAM-BREAK FLOOD ANALYSIS

PLAN AND PROFILE # 1

HYD. AND WATER QUAL. SECT. — FEBRUARY 1984

PLATE 6



SEE LEGEND ON PLATE 6

SCALE IN MILES

0 0.5 1.0

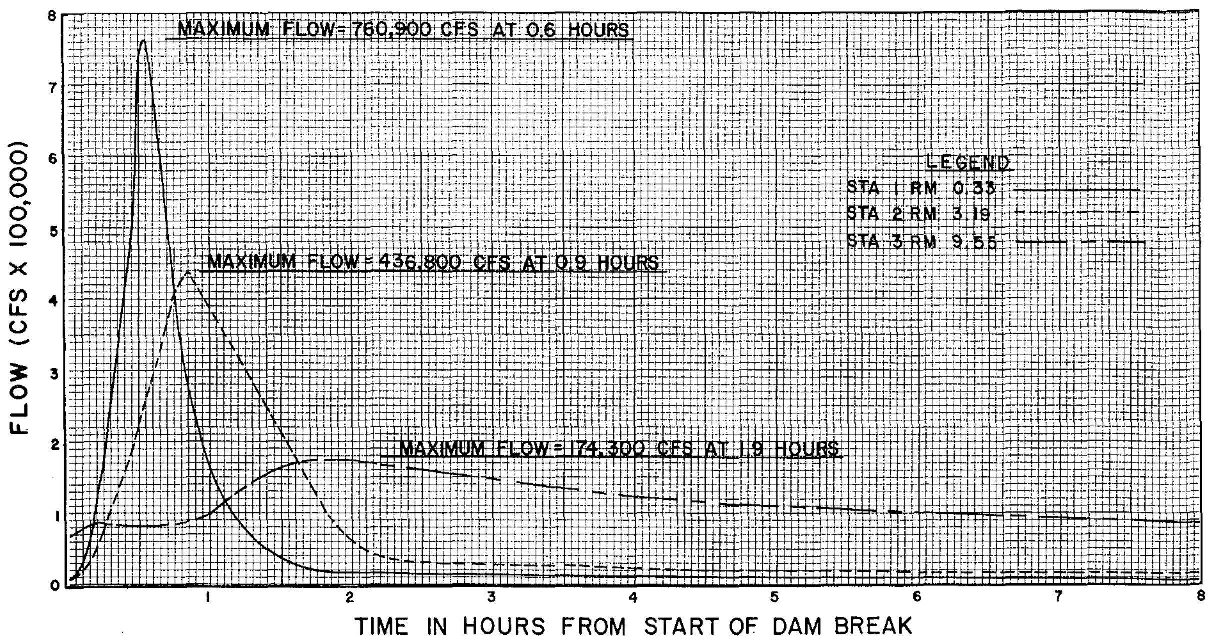
DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
WALTHAM, MASS.

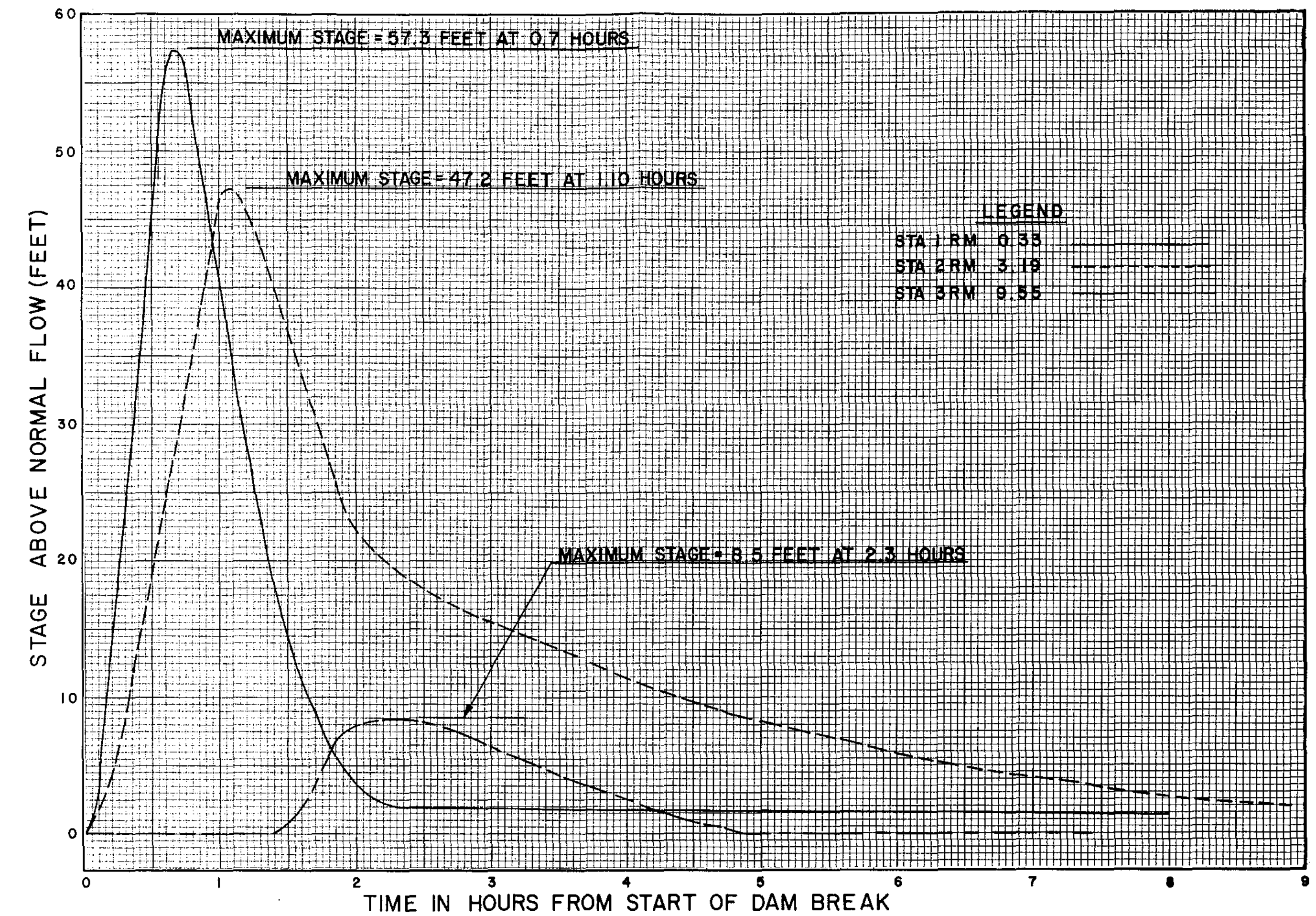
CONNECTICUT RIVER BASIN

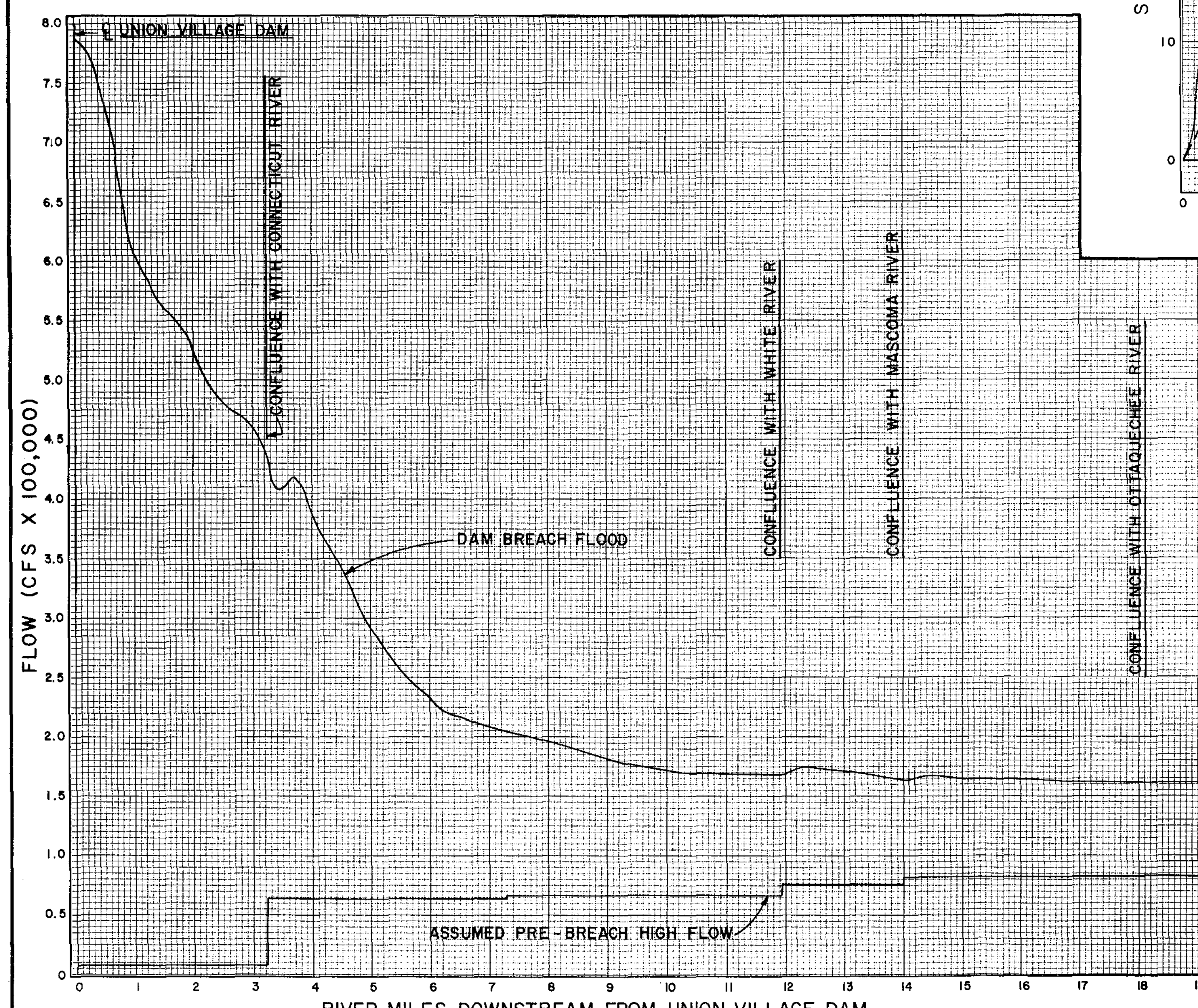
UNION VILLAGE DAM-BREAK FLOOD ANALYSIS

PLAN AND PROFILE # 2

HYD. AND WATER QUAL. SECT. FEBRUARY 1984







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CONNECTICUT RIVER BASIN

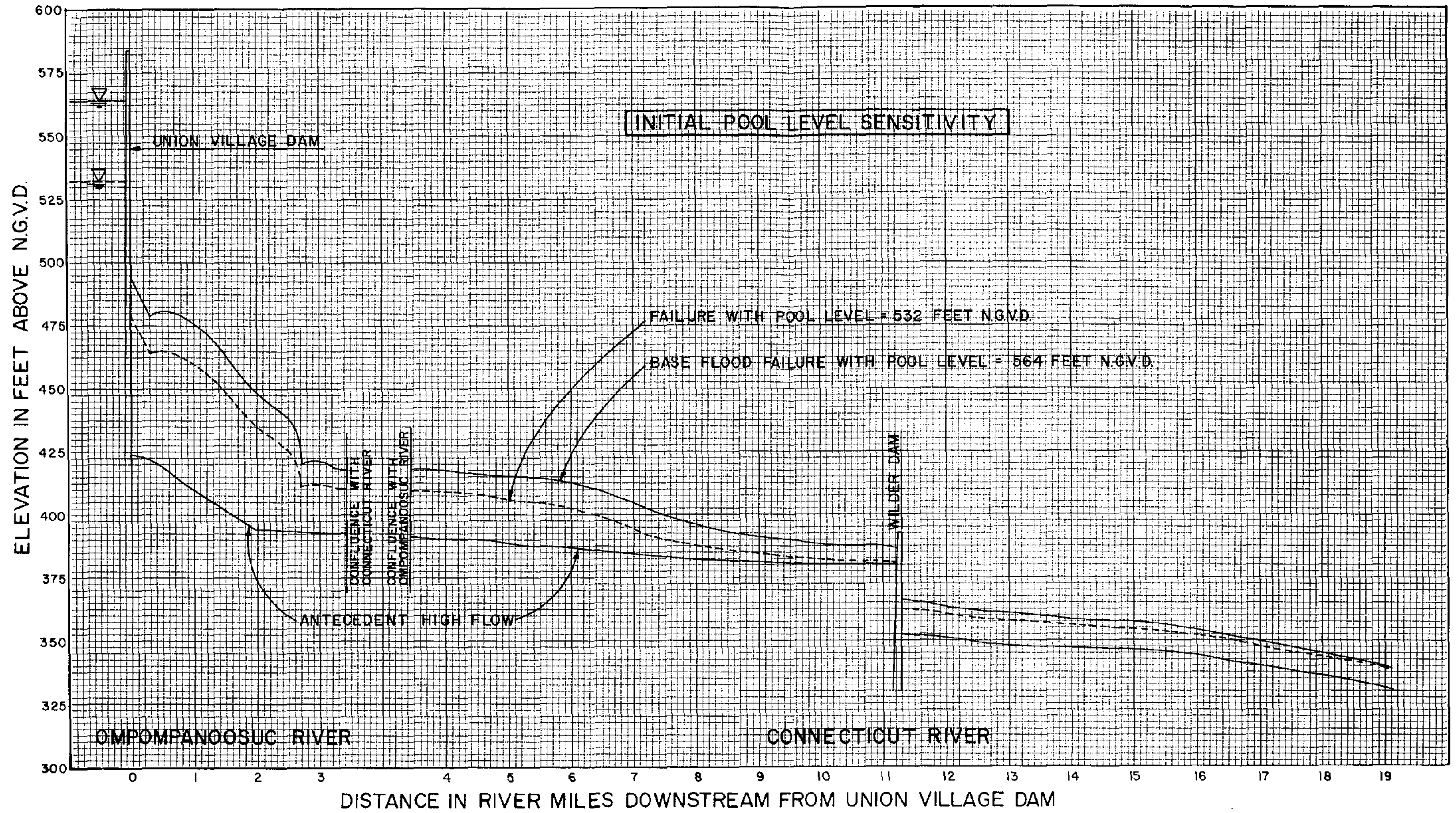
UNION VILLAGE DAM-BREAK FLOOD ANALYSIS

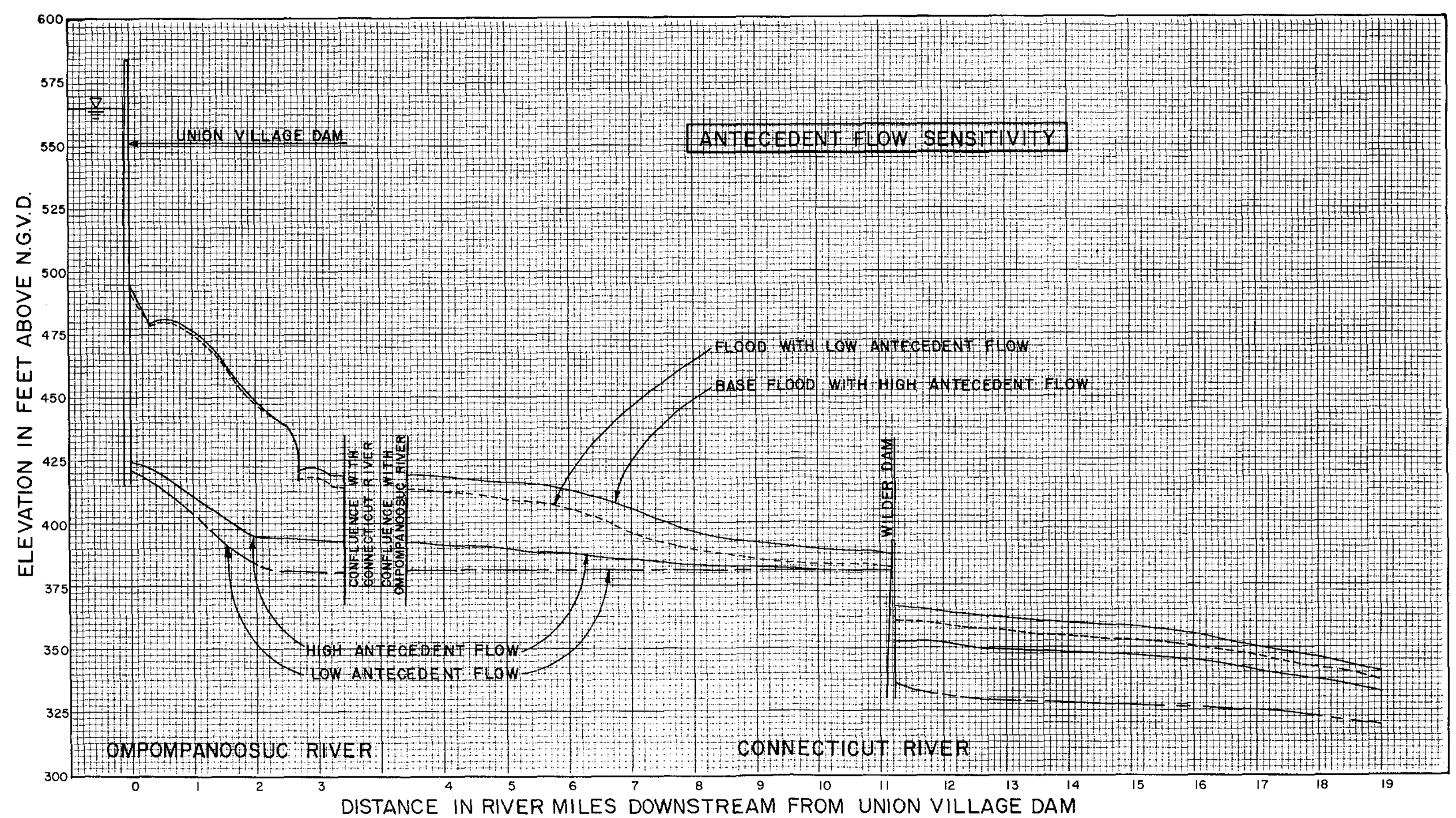
BASE FLOOD DISCHARGES

STAGES AND TIMING

HYD. AND WATER QUAL. SECT. | FEBRUARY 1984

PLATE 8





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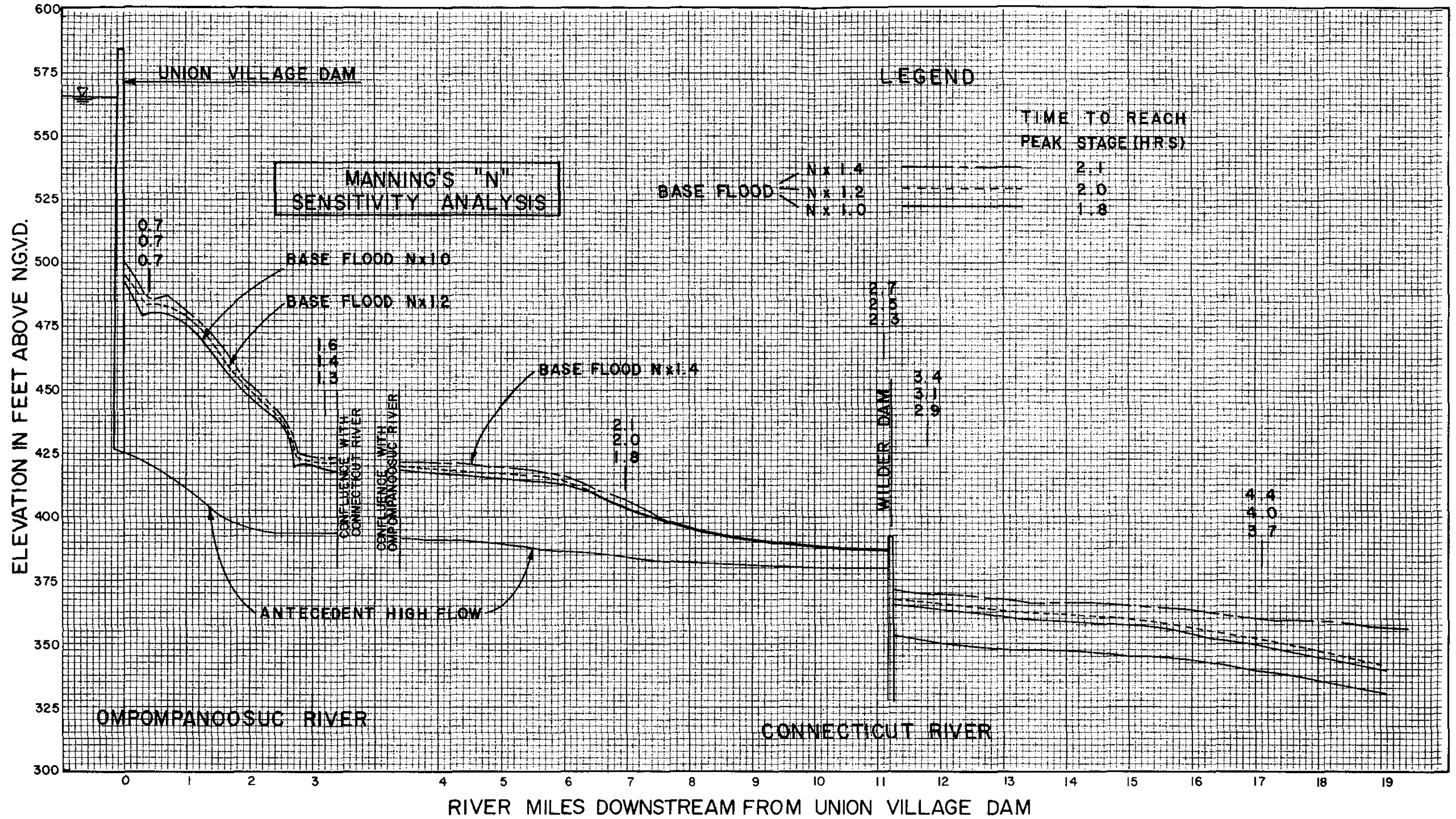
CORPS OF ENGINEERS
WALTHAM, MASS.

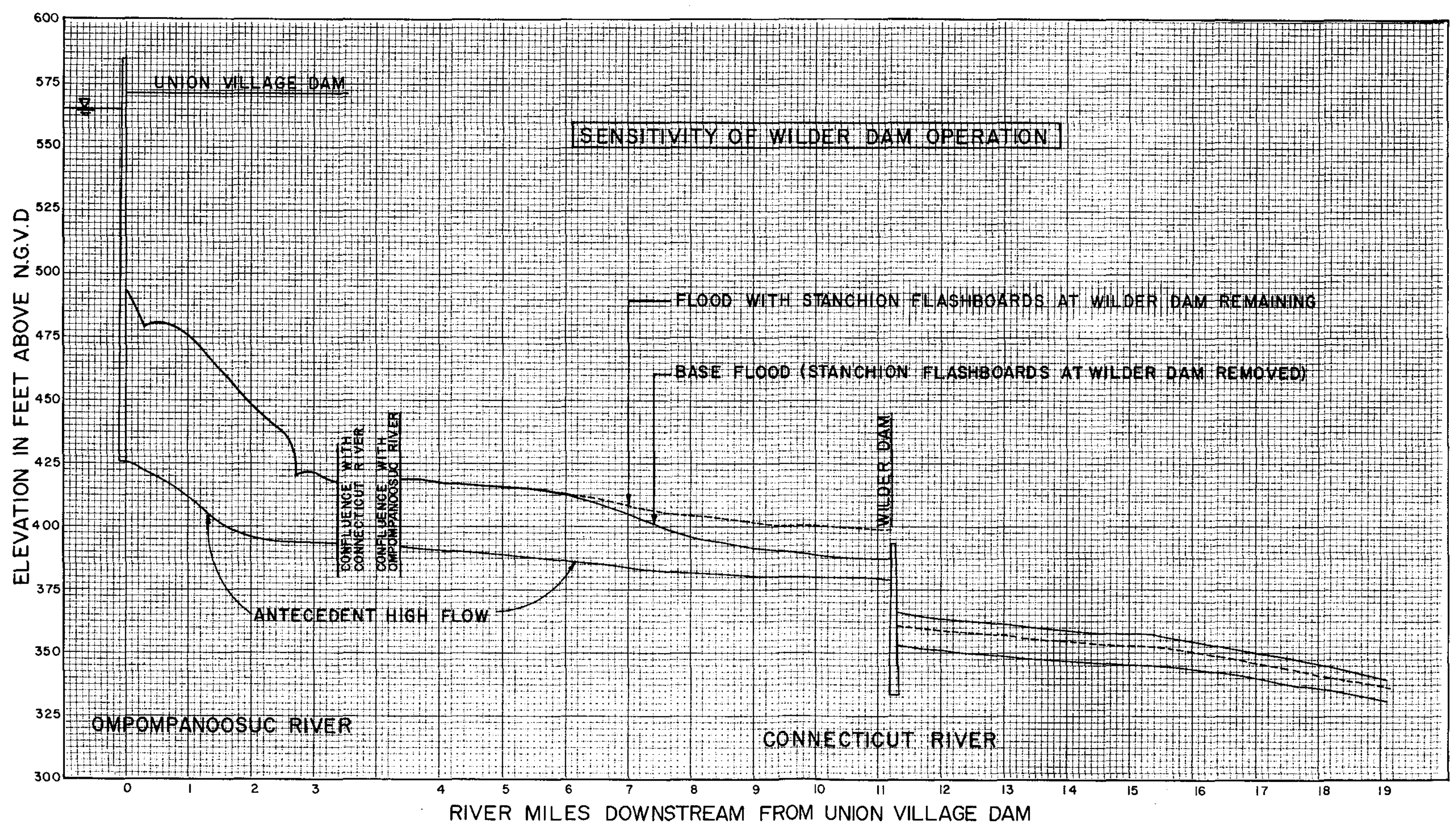
CONNECTICUT RIVER BASIN

UNION VILLAGE DAM-BREAK FLOOD ANALYSIS

SENSITIVITY OF INPUT PARAMETERS # 1

HYD. AND WATER QUAL. SECT. FEBRUARY 1984





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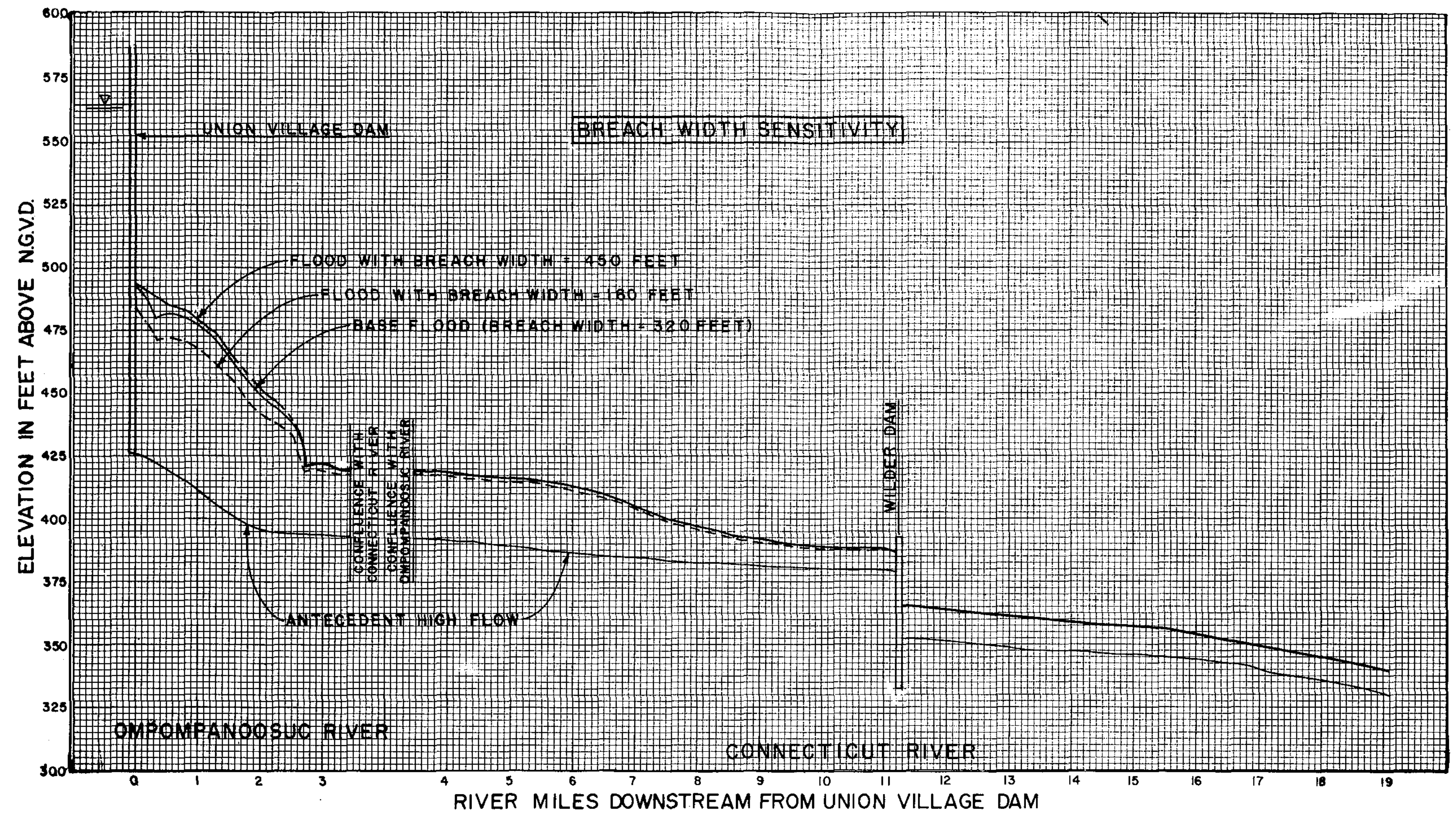
CONNECTICUT RIVER BASIN

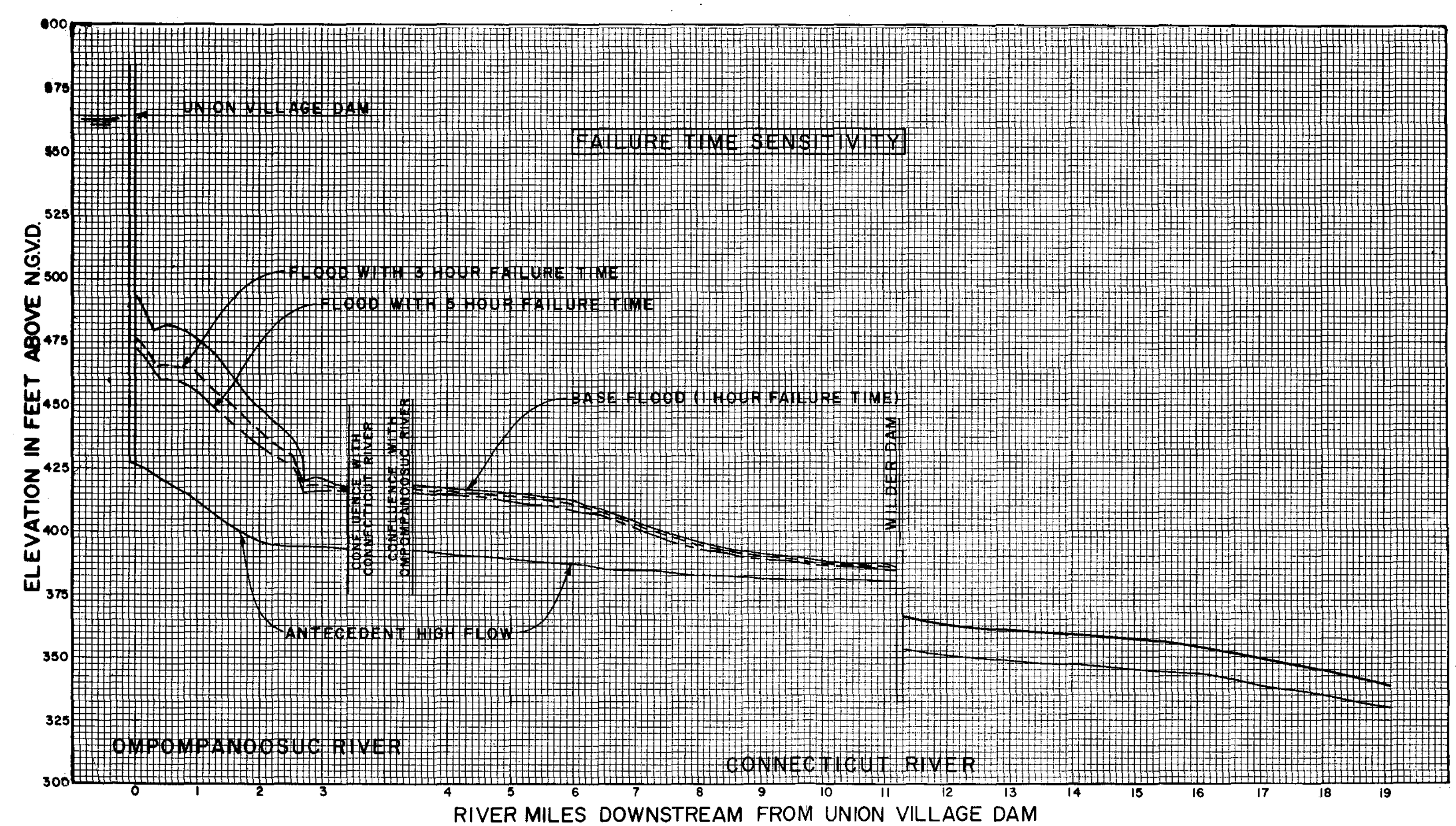
UNION VILLAGE DAM-BREAK FLOOD ANALYSIS

SENSITIVITY OF INPUT PARAMETERS # 2

HYD. AND WATER QUAL. SECT. FEBRUARY 1984

PLATE 10





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WALTHAM, MASS.

CONNECTICUT RIVER BASIN

UNION VILLAGE DAM-BREAK FLOOD ANALYSIS

SENSITIVITY OF INPUT PARAMETERS # 3

HYD. AND WATER QUAL. SECT. FEBRUARY 1984

PLATE 11